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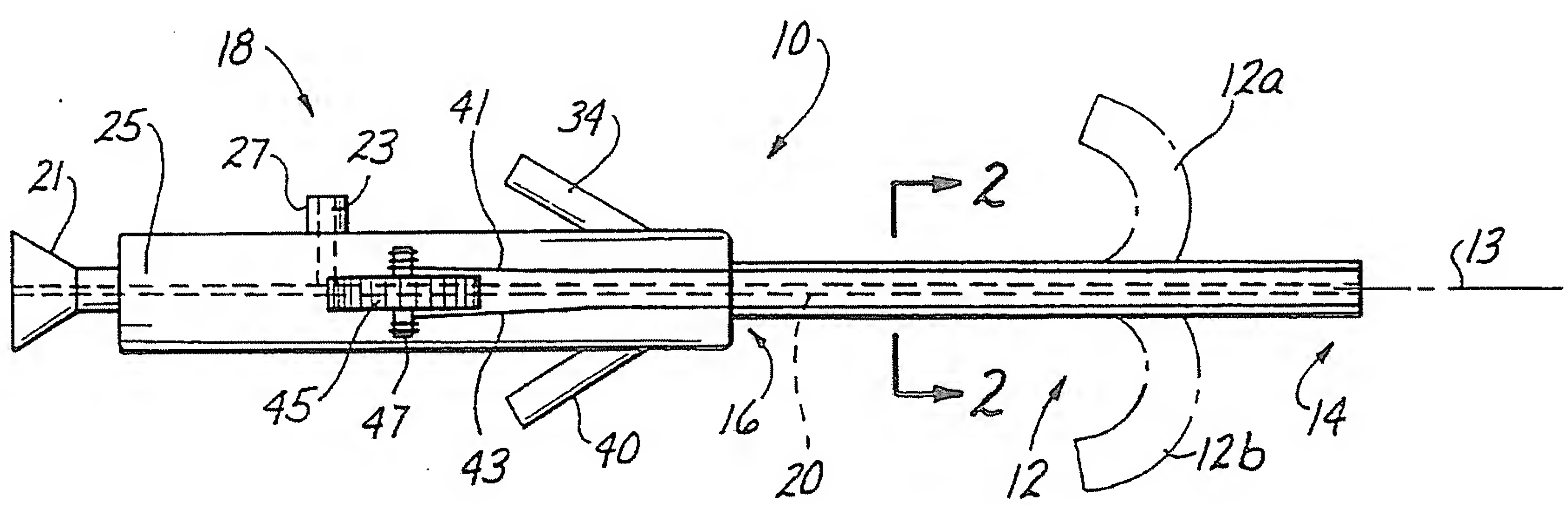

(57) Abstract

An elongate surgical instrument includes a bendable conduit (12) having an axis (13) extending between a distal end (14) and a proximal end (16). The conduit (12) is formed by a tube (29) defining at least one channel (38) and a first section of the channel (38) which is displaced from the axis of the conduit (12). A plurality of elongate elements (23) including a particular element (25) having the highest resistance to bending are disposed in the channel (38) with the particular element (25) disposed in the first section of the channel (38). A cable (41 or 43) is operable to apply a compressive force to the conduit (12) causing the tube (29) and the elements (23) to bend at the first sections. The channel (12) may extend radially of the tube permitting the particular element (25) to buckle away from the direction of the bend.

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STEERABLE ENDOSCOPE WITH BUCKLING ELEMENT

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates generally elongate surgical instruments and more specifically to those instruments which require bending in order to negotiate torturous paths in the body.

Discussion of the Prior Art

With an increasing interest in less invasive forms of surgery, many instruments such as catheters and endoscopes have been developed with elongate configurations facilitating introduction into body conduits. Relying upon body conduits to reach distant locations has necessarily required these instruments to follow a sometimes torturous path into other conduits and tributaries in order to reach or at least view an operative site. The following patents are representative of attempts which have been make to provide these instruments with articulating distal ends:

Inventor	U. S. Patent No.
Adachi	5,073,048
Hammerslag	5,037,391
Hammerslag	4,998,916
Hammerslag	4,921,482
Danieli	4,873,965
Washizuka	4,813,400

Producing bends in these instruments has been particularly difficult in the case of conduits which carry various elements to the operative site. Where these elements have tended to have characteristics including a resistance to bending, significant forces have been required to accomplish any articulation. Large forces have necessarily required larger components to transmit those forces so that the size of some of these instruments has been larger than otherwise desired.

Such is the case with endoscopes which carry elements such as light fibers and image fibers to the operative site. These elements are typically formed from glass and are resistant to bending in the sense that they tend to break when bent around a short radius of curvature. The image fibers typically have the largest diameter and the greatest resistance to bending. Customarily, these image fibers have been disposed centrally, axially of the conduit or endoscope.

Cables operable from a proximal location have been attached to the distal end of these devices. Applying tension to the cables necessarily placed the distal ends in compression creating a tendency for the distal end to bend. Where the elements most resistive to bending, such as the image fibers, have been disposed axially of the devices, they have been bendable generally in all directions, but cables of significant size and strength have been required in order to overcome the bending resistance. The requirement for larger and stronger bending cables has worked against the general necessity to reduce these less invasive surgical instruments to the smallest size possible.

SUMMARY OF THE INVENTION

In accordance with the present invention, the conduit, such as an endoscope, is provided with a particular section where the bending characteristics of the device are significantly enhanced. In this region, the channel of the device which houses the most restrictive element includes portions which are displaced from the axis of the conduit. In this channel, the element most resistant to bending is disposed in a first direction from the axis thereby greatly facilitating the bendability of the conduit in this section. The increased bendability of the conduit is greatest in a second direction which is opposite to the first direction.

In accordance with one aspect of the invention, the image fiber is held off axis in a particular section of the conduit so that bending is not only facilitated for the conduit as a whole, but is generally limited to the particular section.

In another aspect of the invention, two separate sections of the conduit provide for off-axis displacement of the image fiber in opposite directions. In this case, the conduit is most easily bent in one direction at the one section and most easily bent in the opposite direction at the other section.

In a further aspect of the invention, the element most resistive to bending is disposed in an enlarged channel and where it automatically bends to the outside of the curve where the radius of curvature is the greatest. In this off-axis location, bending of the conduit in the opposite direction is facilitated. In a preferred embodiment, the channel housing the image fiber is generally rectangular in

cross-section so that the image fiber is free to buckle to opposite sides of the channel facilitating bending in the opposite direction.

In still a further aspect, the invention includes a method for bending a tube having an axis and a channel extending between a proximal end and a distal end of the tube. The method includes the steps of inserting into the channel an element having a resistance to bending and generating a compressive stress along one side of the conduit. Moving the element in the channel away from the one side of the conduit facilitates bending the conduit along the one side.

These and other features and advantages of the invention will be more apparent with a description of preferred embodiments and the best mode of the concept taken in combination with the associated drawings.

DESCRIPTION OF THE DRAWINGS

Fig. 1 is a top view of a preferred embodiment of an endoscope of the present invention;

Fig. 2 is a radial cross-section view taken along lines 2-2 of Fig. 1;

Fig. 3 is a side cross-sectional view taken along lines 3-3 of Fig 2;

Fig. 4 is a side cross-sectional view similar to Fig. 3 of
an additional embodiment of the present invention;

Fig. 5 is a radial cross-section view taken along lines 5-5 of Fig. 4;

Fig. 6 is a side cross-section view similar to Fig. 4 and illustrating the endoscope bending in one direction;

Fig. 7 is a side elevation view of a subassembly including a pair of bushings associated with the embodiment of Fig. 6;

Fig. 8 is a side elevation view of a further embodiment of the invention including a pair of connectors;

Fig. 9 is a radial cross-section view of still a further embodiment of the invention; and

Fig. 10 is a side cross-sectional view taken along lines 10-10 of Fig. 9.

DESCRIPTION OF PREFERRED EMBODIMENTS AND BEST MODE OF THE INVENTION

An endoscope is illustrated in Figure 1 and designated generally by the reference numeral 10. The endoscope 10 is representative generally of any conduit 12 an axis 13 extending between a distal end 14 and a proximal end 16, and properties for being operated at its proximal end 16 to bend its distal end 14. In the illustrated embodiment, the endoscope 10 includes a handle assembly 18 which is disposed at the proximal end 16 of the conduit 12.

In use, the endoscope 10 provides an instrument which is insertable into a body conduit or cavity where it facilitates the viewing of images at a distant location or

operative site in the body (not shown). In this procedure, the conduit 12 is inserted into a body passage leaving the handle assembly 18 exposed exteriorly of the body. Viewing of an operative site at the distal end 14 of the conduit 12 is accommodated in this particular case by optical fibers 20 which extend from the distal end 14 through the conduit 12 and the handle assembly 18, to an eyepiece 21.

In a particular embodiment, the optical fibers 20 include light fibers 23 and an image fiber 25. The light fibers 23 extend from a light post 27 on the handle assembly 18 through the conduit 12 to the distal end 14 where they provide illumination for an object (not shown) at the distant location or operative site. The image fiber 25 extends from the distal end 14 through the conduit 12 and the handle assembly 18 to the eyepiece 21 at the proximal end of the endoscope 10. It is the purpose of the image fiber 25 to convey images of the object at the operative site for viewing by a surgeon through the eyepiece 12.

In a preferred embodiment, the conduit 12 includes a sheath 29 and an extrusion 32 which defines a plurality of channels or lumens along the conduit 12. In a preferred embodiment, these channels include quadrant lumens 34, which are configured to receive the light fibers 23, a pair of working channels 36, 37 and a central channel 38, which is configured to receive the image fiber 25. The working channels 36 and 37 are accessible through respective side ports 39 and 40 in the handle assembly 18. In the embodiment of Figures 2 and 3 , the central channel 38 extends across the axis 13 into proximity with the sheath 29 on opposite sides of the conduit 12.

It can be appreciated that where the conduit 12 must be pushed through a tortuous passage, it is desirable that its distal end be bendable or otherwise capable of articulation in order to negotiate movement through the tortuous passage. This is particularly desirable in the human body where the conduit 12 may be formed from a relative soft plastic, where the passage is formed of fragile human tissue, and where the extent of the passage is particularly long. It is quite clear that catheters, endoscopes and other types of surgical instruments can benefit from distal tips which are bendable.

Of particular interest to the present invention and the bending of the distal tip 14 is a pair of bending cables 41, 43 which are fixed to the conduit 12 near the distal end 14, and which extend proximally to a thumb wheel 45 which is rotatable on the handle assembly 18.

The thumb wheel 45 is rotatable on a shaft 47 and the pull cables 41 and 43 are wound on the shaft 47 in opposite directions. In the embodiment of Figure 1, when the thumb wheel 45 is rotated in the distal direction, the pull wire 43 is placed in tension and applies a compressive force on the distal end 14 of the conduit 12. This compressive force tends to bend the conduit 12 in a first direction as shown by the dotted lines 12a. When the thumb wheel 45 is rotated in the proximal direction, the pull wire 41 is placed in tension and applies a compressive force to the distal end 14 of the conduit 12. This compressive force tends to bend the conduit 12 in a second direction as shown by the dotted lines 12b.

The pull cables 41 and 43 in the illustrated embodiment are disposed in the central channel 38. The pull cable 41 is disposed in a first lateral direction from

the axis 13 as shown by an arrow 49. Similarly the pull cable 43 is disposed in a second direction from the axis 13 as shown by an arrow 52. The arrow 52 extends generally in a direction opposite to the arrow 49 so that a line drawn between the cables 41 and 43 in the cross section view of Figure 2 passes through the axis 13.

In a particular embodiment illustrated in Figure 3, the central channel 38 include two axial sections 54 and 56. In the section 54, the image fiber 25 is moved off the axis 13 in the first direction 49. In the second axial section 56, the image fiber 25 is moved off the axis 32 but in the opposite direction 52. In this embodiment, the image fiber 25 is fixed or otherwise held in these off-axis positions in the respective axial sections 54 and 56.

This placement of the image fiber 25, which has a significant resistance to bending, is of particular interest to the present invention. When the fiber 25 is moved to a side of the conduit 12 which is opposite to that of one of the pulling cables 41, 43 the moment arm associated with the force applied to the respective pulling cable is increased. This increase in the moment arm decreases the amount of force required to bend the fiber 25 and consequently the conduit 12.

This phenomena can be more easily understood with reference to Figure 3 where it can be appreciated that pulling on the cable 43 will cause the conduit 12 to bend at the section 56 where the moment arm is greatest between the cable 43 and the fiber 25. This moment arm is illustrated by an arrow 58. Similarly, if the cable 41 is pulled, the conduit 12 will tend to bend at the section 54 where the moment arm between the cable 41 and the fiber 25

is the greatest. This moment arm is illustrated by an arrow 61.

In an embodiment such as that described with reference to Figure 3, the image fiber 25 can be fixed in its S-curve configuration, by potting the fiber 25 within the channel 38. In a different embodiment, the channel 38 can be left open providing a relatively wide slot within which the fiber 25 can move. While it might appear that if the fiber 25 is not fixed against the outer edge of the channel 38 it will automatically be drawn to the inner edge, this has been found not to be the case. In fact, if the fiber 25 is free to move axially within the conduit 12, it will automatically flop or buckle to the side of the channel 38 which is opposite the direction of bending.

This will be apparent with reference to Figure 4 wherein the conduit 12 includes the outer sheath 29 which is disposed around an outer spring 63. A pair of axially spaced connectors or bushings 65 and 67 are disposed at opposite ends of the bending section 68 and hold the fiber 25 axially of the conduit 12. Between the bushings 65 and 67, the channel 38 extends laterally to the outer spring 63. While the fiber 25 may have a generally fixed relationship with the distal bushing 67, it is preferably free to move axially within the proximal bushing 65. The bushing 67 can be fixed to the fiber 25 by epoxy 69 which is potted into the distal end 14 of the spring 63. The cables 41, 43 can also be fixed in this epoxy 69 at respective nodes 72 and 74. The distal end 14 can be cut and polished in a manner customary in the art.

With the foregoing structural characteristics, the application of compressive stresses to the conduit 12 will cause the fiber 25 to automatically move or buckle in a

direction away from the compressive force. More specifically, if the cable 41 is pulled, the fiber 25 will move away from the compressive forces created by the cable 41. For example in Figure 4, the fiber 25 would move to a position shown by the dotted lines 25a. Similarly, if the cable 43 is pulled, the fiber 25 will move in a direction away from the compressive forces created. Thus in Figure 4, the fiber 25 would move to a position indicated by the dotted lines 25b. As the fiber 25 moves away from the cable 41, 43 being pulled, the conduit 12 will bend toward the cable 41, 43 being pulled.

Initially, the force applied to the cable 41 or 43 is an axial force which is resisted by the entire column strength of the fiber 25. With a moment arm generally limited to the radius of the conduit 12, a relatively large force is required on the cable 41 or 43 to start the movement or bending of the fiber 25. However, as the fiber 25 bends, this moment arm increases so that a reduced force is required to continue the movement of the fiber 25 and the bending of the conduit 12.

The bending of the section 68 can be facilitated by enhancing the bending characteristics of the spring 63 in this section. In the illustrated embodiment, the spring 63 includes a multiplicity of convolutions 64 which are widely spaced in the bending section 68 but are narrowly spaced or closed on either side of the section 68. Where the convolutions 64 are widely spaced, the bending of the spring 63 is greatly enhanced.

It is preferred that the convolutions 64 be spaced in the bending section 68 not by permanent deformation, but rather by an axial force applied to stretch the spring 63 in this section 68. In the embodiment of Figure 4, this

force is provided by permanently attaching the bushings 65 and 67 to the sheath 29. Thus the sheath 29 provides a compressive element 76 which is disposed outwardly of the bushings 65, 67 and maintains the spacing of the convolutions 64 against the bias of the spring 63. With an appropriate separation of the bushing 65, 67, the convolutions 64, of the spring 63 will be spaced in the bending section 68.

In the embodiment in Figure 6, the compressive element 76 takes the form of an interior element 78 which is disposed interiorly of the outer spring 63 but outside the fiber 25. It is the purpose of this inner compressive element 78 to maintain the separation of the bushing 65 and 67 in order to space the convolutions 64 of the spring 63. Since the concept of the present invention is facilitated by enhancing the bending of the compressive element 78, it may be desirable in a particular embodiment to configure the compressive element 78 in the form of a second spring. It will be noted that in this embodiment, an outer sheath, such as that designated by the reference numeral 29 in Figure 4, is not required to maintain the spacing of the convolutions 64.

Some of these embodiments can benefit from a subassembly 81 best illustrated in Figure 7. This subassembly 81 greatly facilitates the manufacturing process by combining some of the elements of the endoscope 10 prior to final assembly. In this case, the subassembly 81 includes the bushings 65 and 67 which are mounted on the image fiber 25 and maintained in the preferred space relationship by the compression member or spring 78.

The configuration of the bushing 65 and 67 are best illustrated in this view of Figure 7. These bushings 65,

67 each include a subchannel 83 which is disposed in an axial direction and sized to accommodate movement of the pull cable 41 through the channel 83. Similarly, the bushings 65, 67 are configured with an axially directed subchannel 85 to accommodate the pull cable 43. The bushings 65, 67 are also configured with an axial passage 87 through which the fiber 25 extends.

It is desirable that this passage 87 have a diameter sufficiently large to permit the fiber 25 to move axially relative to the bushing 65. This feature is not necessarily required for the distal bushing as it is intended that the fiber 25 have a generally fixed relationship with the bushing 67. The passage 87 in the bushings 65, 67 can be provided with an enlarged recess 88 which is configured to receive the compression member 78. The passage 87 can also be flared along a curve 89 where the compression member 78 enters the respective bushings 65, 67.

A further embodiment of the invention is illustrated in Figure 8 wherein some of the features associated with the bushings 65, 67 are provided by a pair of connectors 92 and 94. These connectors 92, 94 have an outer wall 96 in the shape of a cylinder and an inner wall 98 forming a septum radially of the outer wall 96. The septum 98 is suitably apertured to form the passage 87 and the subchannels 83 and 85 as previously discussed.

The connectors 92, 94 are intended to connect two separate outer springs 101 and 103. The spring 101 has characteristics similar to those discussed with reference to that portion of the spring 63 having the closed convolutions 64. The spring 103 has characteristics similar to those discussed with reference to the section 68

of the spring 63 having the spaced convolutions 64. Thus, in a preferred embodiment, the spring 103 has spaced convolutions while the spring 101 has closed convolutions. The ends of the respective springs 101, 103 are adapted to fit within the cylindrical outer walls 96 of the connectors 92, 94, in abutting contact with the septum 98. The springs 101, 103 are preferably held within the connectors 92, 94 in contact with the septum 98 by a suitable epoxy.

In the embodiment of Figure 8, the spring 103 can be permanently deformed to provide for the spaced convolutions or can be left in compression in the manner previously discussed. In the latter case, a compression member either in the form of the outer sheath 29 or the inner spring 78 can be used to maintain the spring 103 in its expanded state. Once again, the interior spring 78 is preferred since it is noncompressible in an axial direction but highly bendable in a radial direction.

These same characteristics are provided by a compression member 78 best illustrated in Figures 9 and 10. In this case, the compression member 78 includes a multiplicity of discreet washers 105 which surround the fiber 25. These washers 105 each are defined by radial surfaces 107 and 109 which are smooth and therefore slide easily relative to each other. Lateral surfaces 112 and 114 are spaced to slide in close proximity to the sides of the channel 38. This is best illustrated in Figure 9 where the washers 105 are closely stacked along the fiber 25 between the septums 98 of the respective connectors 92 and 94. These washers 105 function similarly to the previously mentioned compression member 78 in maintaining the separation of the connectors 92, 94. However, with the radial surfaces 107 and 109 freely movable relative to each

other, the washers 105 move more easily in a lateral direction to accommodate the buckling fiber 25 in the manner and for the purpose previously discussed. This lateral movement is illustrated by the arrows 116 in Figure 9.

Also associated with the present invention is a method for bending a conduit, such as the spring 63, having the axis 13 and a channel 38 extending between a proximate end 16 and a distal end 14. The method includes the step of inserting into the channel 38 one or more elements, such as the light fibers 23 and the image fiber 25, each of which has some resistance to bending. One of these elements will have the highest resistance to bending. That element in the embodiments previously discussed is the image fiber 25. The method includes the step of generating a compressive stress along one side of the conduit 12. This stress can be generated by pulling either on the cable 41 or the cable 43. If the cable 43 is pulled, the compressive stress occurs along the conduit 12 in proximity to the cable 43.

A step for moving the most resistive element, such as the fiber 25, within the channel 38, may also be required in a particular method. Movement of this fiber 25 is preferably in a direction away from the side of the conduit 12 which has been placed in compression. If the cable 43 is pulled, the side in compression is the lower side of the conduit 12 in Figure 6. In accordance with a preferred method, the fiber 25 is moved or buckled upwardly in Figure 6 away from the side in compression.
Finally, a preferred method may include the step of bending the conduit 12 along the side in compression while the fiber 25 is displaced to the opposite side of the conduit 12.

In a particular method, the step of moving the fiber 25 in the channel 38 away from the compressed side of the conduit 12 may include the step of fixing the fiber 25 in this off-axis location. This method could result in the embodiment of Figure 3. In other embodiments which accommodate the buckling, the fiber is free to move from a first position, which may be an axial position, to a second position, which is off-axis and spaced from the compressive forces.

It can be appreciated that it is preferable that the pulling cables 41 and 43 be disposed at opposite sides of the channel within which the fiber 25 is free to buckle. This configuration makes it possible to create the compressive forces at one side of the channel while the fiber is free to move in the directly opposite direction to the other side of the channel.

If, in a particular embodiment, the cables 41, 43 cannot be disposed at opposite sides of the channel 38, the conduit 12 will nevertheless bend if the pulling force is disposed in a direction from the axis 13 which has at least one component along the width of the channel 38. This component will cause the fiber 25 to move within the channel so that at least some of the advantages associated with the present invention can be achieved.

In a particular method wherein the outer spring 63 is provided, the convolutions 64 of this spring can be spaced to place the section 68 of the spring in compression. The spacing of the convolutions 64 as well as the compression characteristics associated with the bias of the spring 63 will greatly facilitate the bending of section 68.

This step of maintaining the spaced convolutions may include the steps of providing bushings at either end of the spaced convolutions and maintaining those bushings in a axially spaced relationship, for example, with the outer sheath 29 or the inner compression member 78. These compression members can be provided with characteristics prohibiting axial compression but permitting radial movement of the fiber 25.

In a preferred method of operation, the invention includes the steps of applying an initial compressive force off the axis 13 of the conduit 12, that initial force being sufficient to cause the fiber 25 to move off axis in the opposite direction. Some bending of the conduit 12 may occur with this initial buckling of the fiber 25. The application of additional compressive force will increase the bending of the conduit 12.

It should be specifically noted that the amount of initial force required to accommodate the buckling of the fiber 25 is never greater than that which would be required to bend the conduits of the prior art where the fiber 25 is maintained in an axial location. As a result, the amount of force required to bend the distal end 14 of the conduit 12 is greatly reduced in accordance with the present invention.

It will be appreciated that this invention is not particularly dependent upon the materials which form the various elements of the endoscope 12. Thus the concept of the invention can be embodied with metal, plastic and elastomeric components which may provide particular advantages in certain embodiments. It will also be apparent that the compression element 78 which maintains the spacing of the bushings 65, 67 and the connectors 92,

94, can also take various forms. Thus, this compression element could be a solid, cylindrical tube, a spring, or the discrete washers 105.

The channel 38 may also take various forms. The channel could have a restricted height but extend laterally to accommodate movement of the buckling fiber 25 only in two opposite directions. Alternatively, the channel 38 could occupy the entire interior region of the tube or spring 63 in which case it will automatically buckle to a location opposite to that of the compressive bending force.

Given the wide variety of substitutions, all within the breadth of this concept, the broad scope of the invention should not be limited to the drawings and the described embodiments, but should be ascertained only with reference to the following claims.

CLAIMS

1. A bendable conduit having an axis extending between a distal end and a proximal end, the conduit comprising:

a tube having portions defining at least one channel extending between the distal end and the proximal end of the conduit, the portions of the tube including first portions which define a first section of the channel which is displaced from the axis of the conduit;

a plurality of elongate elements extending through the channel and each having a resistance to bending;

a particular one of the elements having the highest resistance to bending and being disposed in the first section of the channel displaced from the axis of the conduit; and

means for applying a compressive force to the conduit distally of the first section of the channel to bend the tube and the elements at the first portion of the tube.

2. The conduit recited in Claim 1 wherein the tube has a wall and the first tube portions are disposed in close proximity to the wall of the tube.

3. The conduit recited in Claim 1 wherein the tube has the configuration of a spring.

4. The conduit recited in Claim 1 wherein the channel defining portions include the first portions which receive the particular element displaced from the axis of the conduit, and second portions which receive the particular element along the axis of the conduit.

5. The conduit recited in Claim 4 wherein the particular element in the first section of the channel is displaced from the axis of the conduit in a first direction and the applying means applies the compressive force to the conduit at a point which is disposed relative to the particular element in a second direction having a component opposite to the first direction.

6. The conduit recited in Claim 5 wherein the second direction is opposite to the first direction and the conduit bends generally in the second direction so that the particular element has the largest radius of curvature of any of the elements.

7. A conduit having an axis extending between a proximal end and a distal end and being relatively bendable at a first section and relatively unbendable at a second section, the conduit comprising:

a tube having portions defining a channel extending between a distal end and a proximal end of the conduit, the channel at the first section of the conduit including a particular region which is displaced in a first direction from the axis of the conduit;

an elongate element extending through the channel and the particular region of the channel, the element having characteristics including a resistance to bending; and

means for applying a compressive force to the conduit to bend the conduit at the first section and in a direction having a component opposite to the first direction.

8. The conduit recited in Claim 7 wherein:

the element is a particular element included among a plurality of elements each extending along the conduit; and

the particular element has the highest resistance to bending of any of the elements.

9. The conduit recited in Claim 7 wherein:

the tube at the first section of the conduit has a first resistance to bending;

the tube at the second section of the conduit has a second resistance to bending; and

the second resistance is greater than the first resistance.

10. The conduit recited in Claim 9 further comprising:

a spring included in the tube and having a multiplicity of convolutions;

the convolutions in the first section of the conduit having a first spacing;

the convolutions in the second section of the conduit having a second spacing; and

the first spacing of the convolutions being greater than the second spacing of the convolutions.

11. The conduit recited in Claim 10 further comprising:

a first connector engaging the spring in the second section distally of the first section;

a second connector engaging the spring in the second section proximally of the first section; and

compression means separating the first connector from the second connector to increase the spacing of the convolutions in the first section of the conduit.

12. The conduit recited in Claim 11 wherein:

portions of the first connector and the second connector define the channel;

the element has a fixed relationship with the portions of the first connector; and

the element has a slidable relationship with the portions of the second connector.

13. The conduit recited in Claim 11 wherein the compression means has characteristics for inhibiting axial compression while permitting radial movement of the compression means.

14. The conduit recited in Claim 13 wherein the compression means includes a second spring.

15. The conduit recited in Claim 13 wherein the compression means includes a plurality of discreet washers axially stacked but slidable radially of each other.

16. The conduit recited in Claim 12 wherein the channel extends generally axially through the first connector and the second connector.

17. A method for bending a tube having an axis and a channel extending between a proximal end and a distal end, including the steps of:

inserting into the channel an element having a resistance to bending;

generating compressive stresses along one side of the conduit;

moving the element in the channel away from the one side of the conduit; and

bending the conduit along the one side of the conduit.

18. The method recited in Claim 17 wherein the element is a particular element and the inserting step includes the step of inserting into the channel a plurality of elements including the particular element which has a higher resistance to bending than any of the other elements.

19. A bendable conduit having an axis extending between a distal end and a proximal end, the conduit comprising:

a tube forming a channel extending between the distal end and the proximal end of the conduit;

first portions of the channel extending from the axis in a first radial direction;

an elongate element disposed in the channel and extending from the proximal end to the distal end of the conduit, the elongate element having a resistance to bending; and

means for causing the element to move into the first portions of the channel to facilitate bending the conduit away from the first direction.

20. The conduit recited in Claim 19 further comprising:

second portions of the channel extending from the axis in a second radial direction different from the first radial direction; and

means for causing the element to move into the second portions of the channel to facilitate bending the conduit away from the second direction.

21. The conduit recited in Claim 20 wherein the first causing means comprises a wire disposed in proximity to the second portions of the channel.

22. The conduit recited in Claim 20 wherein the second causing means comprises a wire disposed in proximity to the first portions of the channel.

23. The conduit recited in Claim 20 wherein the first direction is generally opposite to the second direction.

24. A bendable conduit having an axis extending between a distal end and a proximal end, the conduit comprising:

a spring having a multiplicity of convolutions and forming a channel extending between the distal end and the proximal end of the conduit;

a first axial section of the spring disposed generally at the distal end of the conduit and having a first resistance to bending;

a second axial section of the spring disposed generally at the proximal end of the conduit and having a second resistance to bending greater than the first resistance to bending of the first section;

an elongate element disposed in the channel and extending from the proximal end to the distal end of the conduit;

means for increasing the spacing for the convolutions in the first section and for maintaining the increased spacing of the convolutions against the bias of the spring.

25. The conduit recited in Claim 24 wherein the increasing means includes a first connector having a fixed relationship with the spring between the first section and the second section of the spring;

a second connector having fixed relationship with the spring distally of the first section; and

compression means for maintaining the first connector and the second connector in a spaced relationship, with the convolutions of the spring having the increased spacing.

26. The conduit recited in Claim 24 wherein the channel includes portions which extend from the axis radially outwardly of the spring, and the conduit further comprises means for moving the elongate element into the radial portions of the channel to facilitate bending the conduit of the first axial section of the conduit.

27. The conduit recited in Claim 26 wherein the moving means is disposed in the channel.

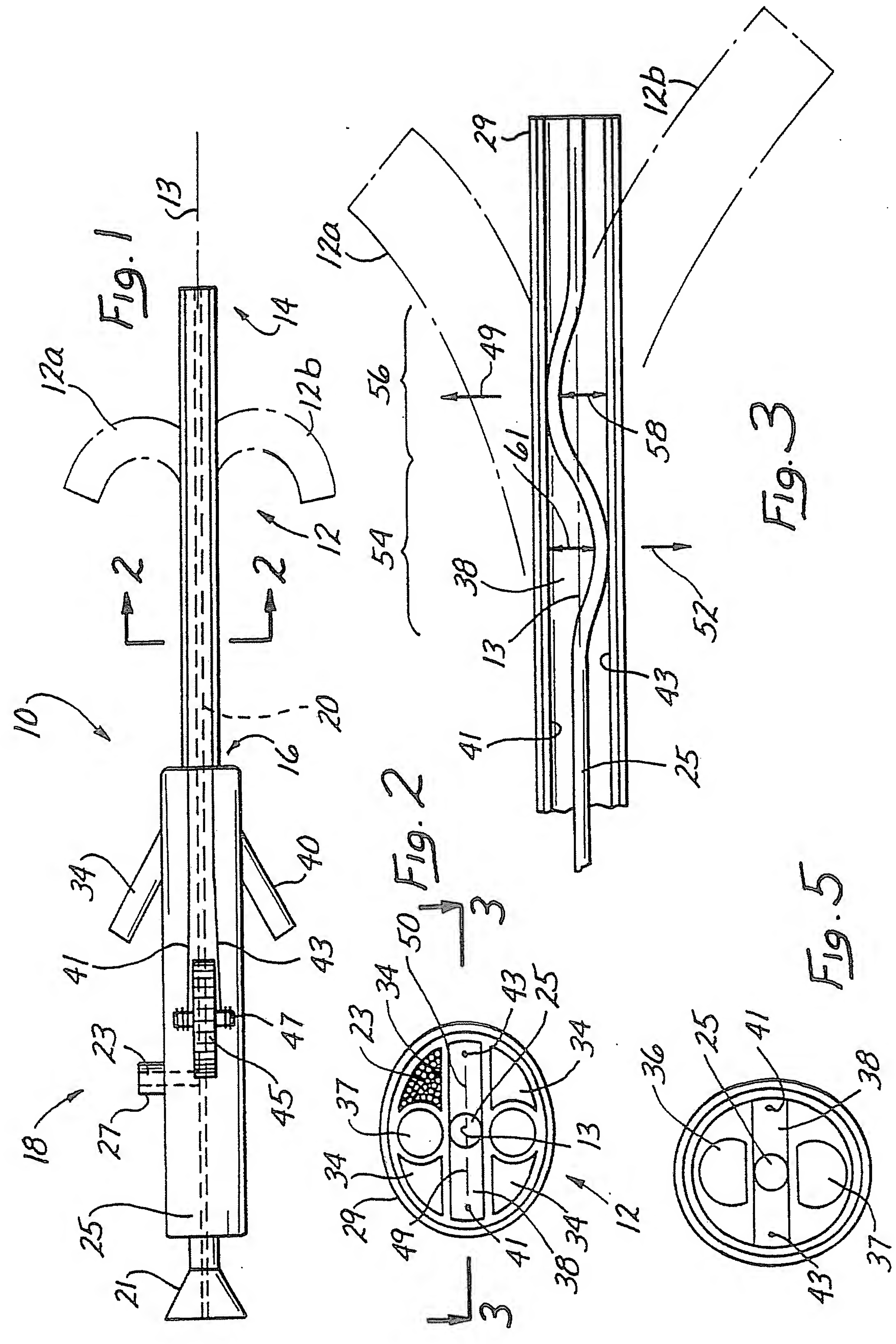

Fig. 1

Fig. 2

Fig. 3

Fig. 5

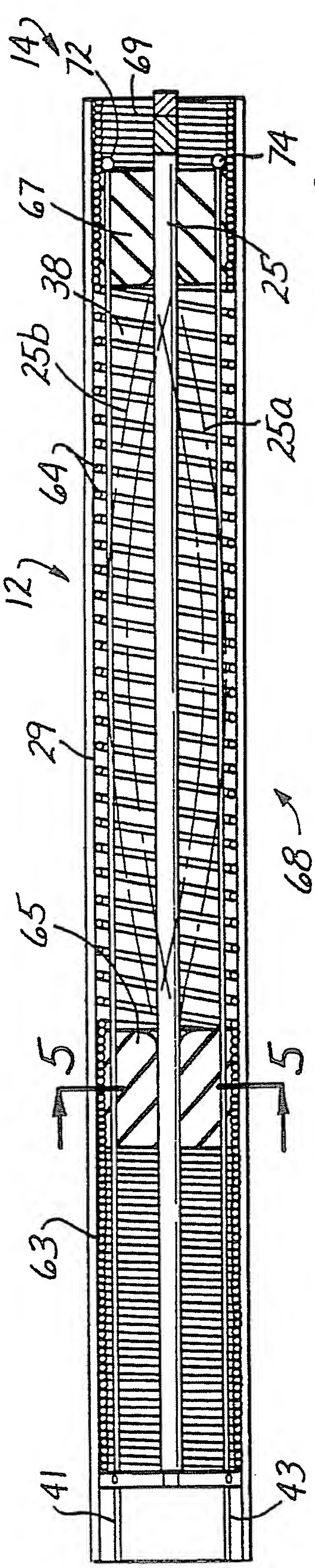

Fig. 4

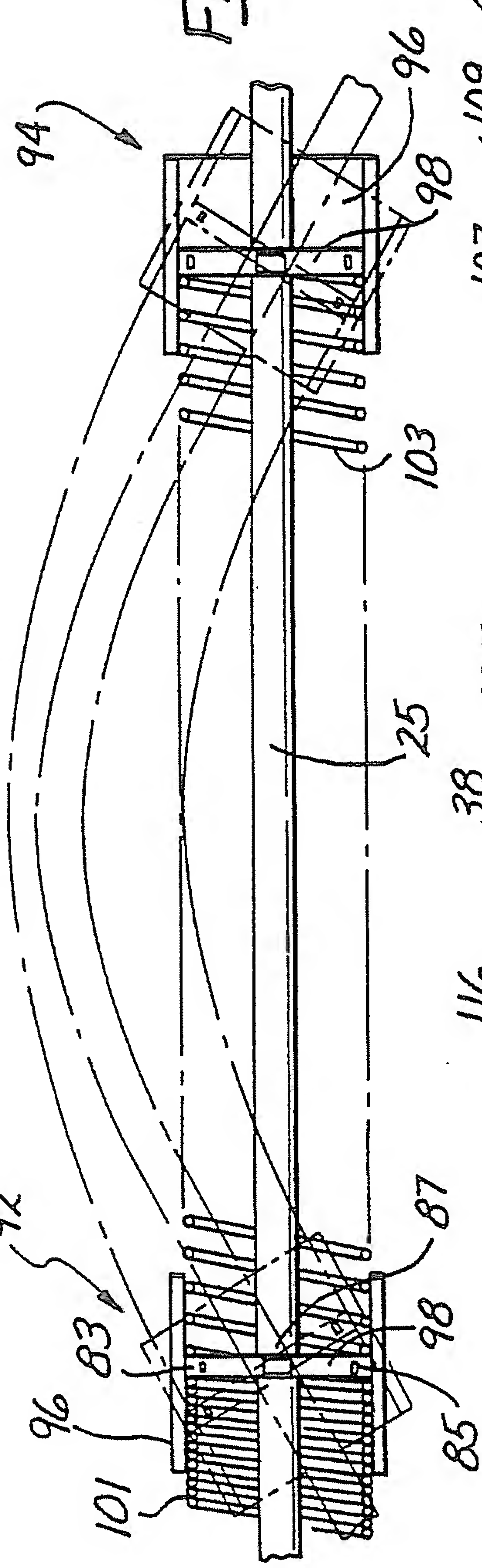

Fig. 8

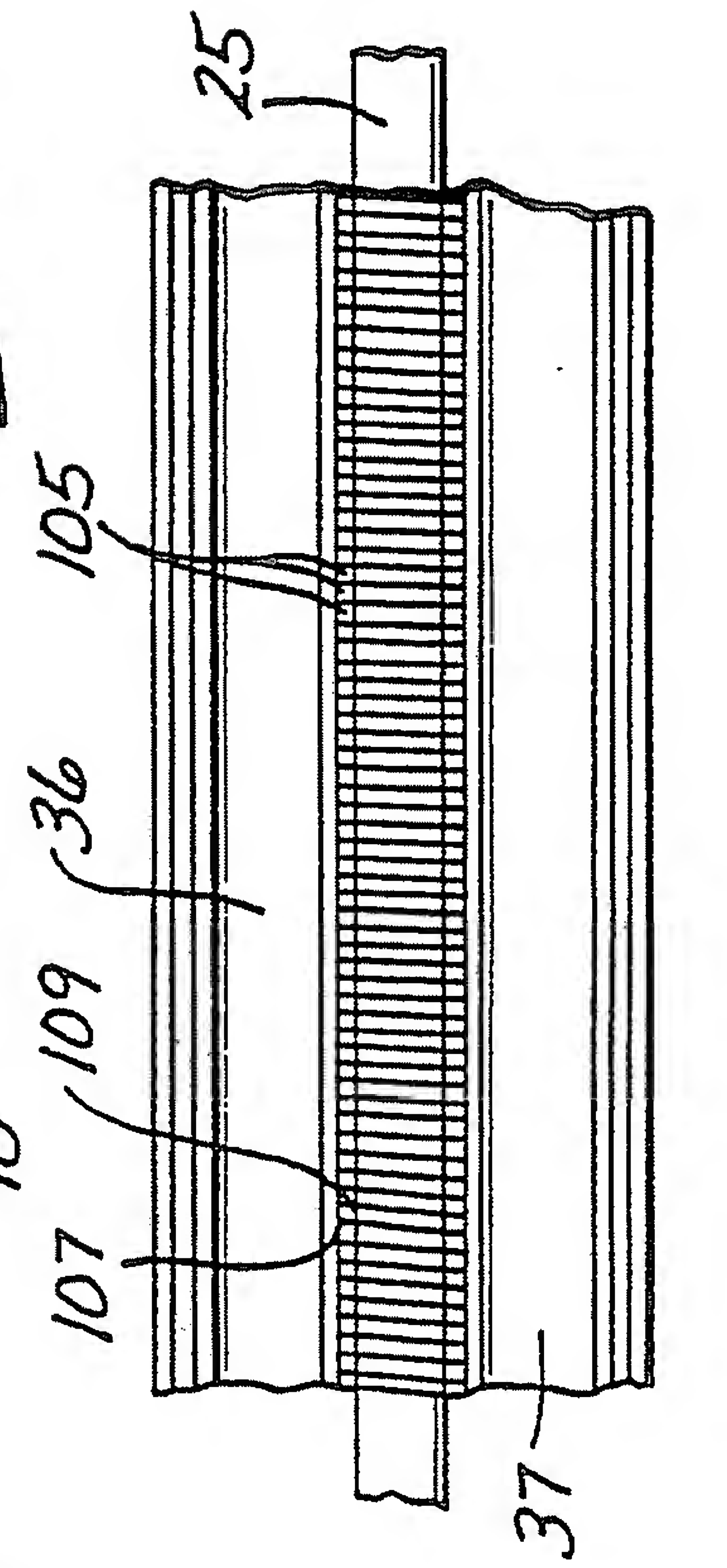

Fig. 10

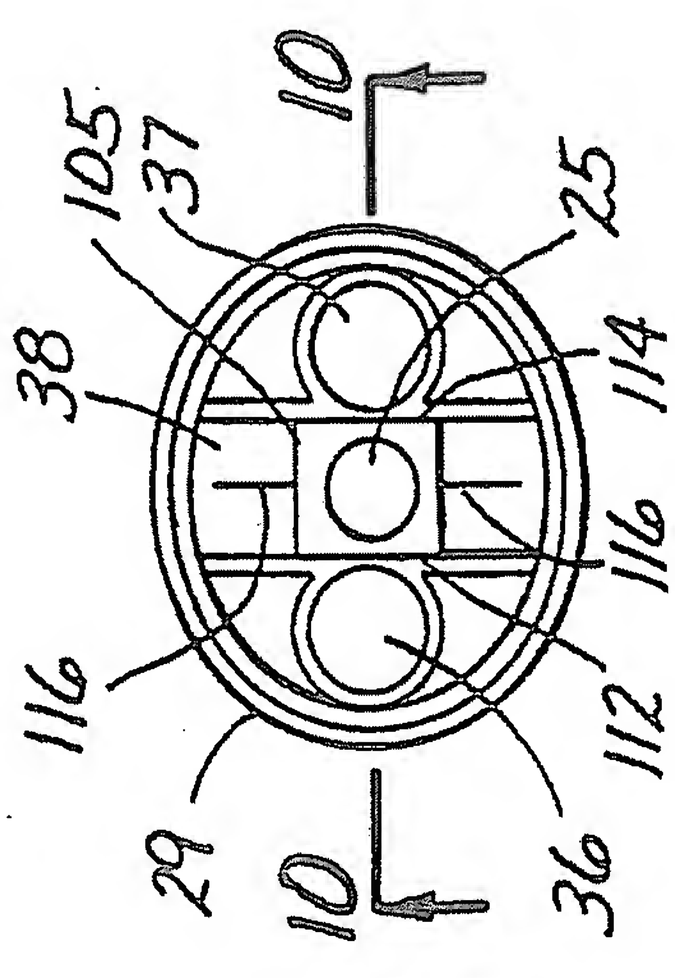

Fig. 9

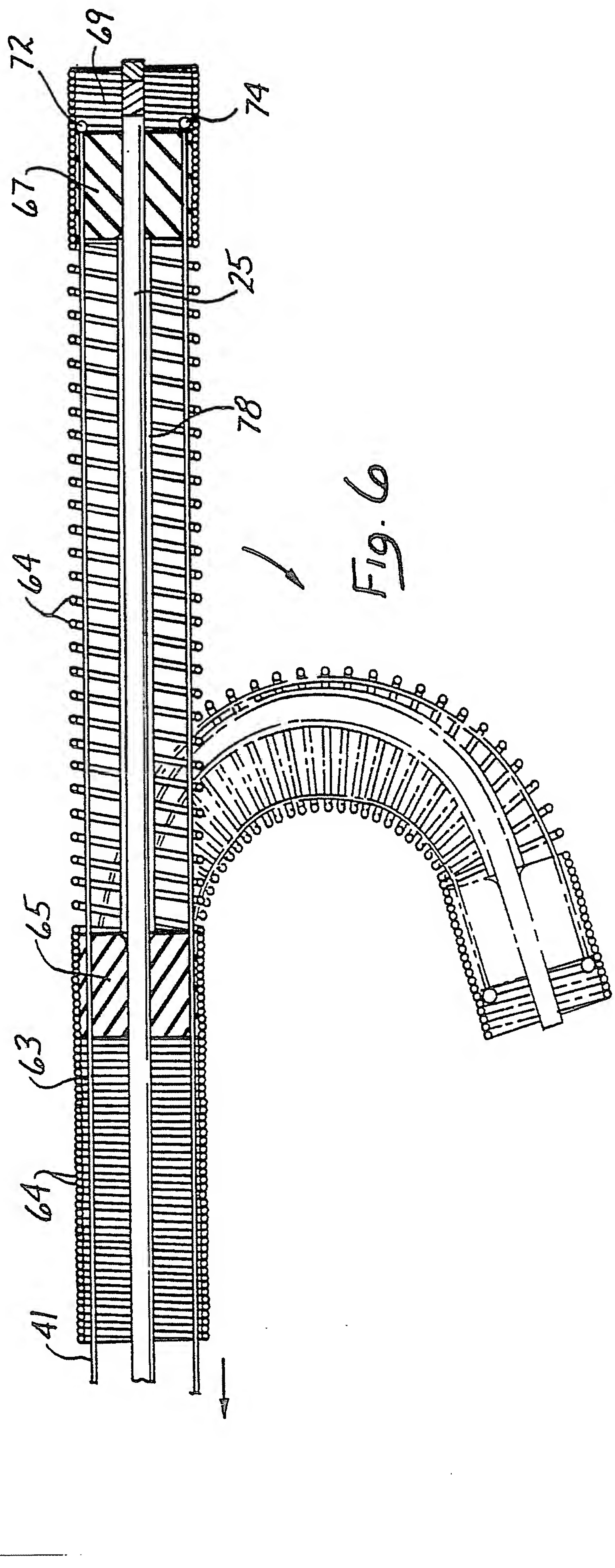
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Fig. 6

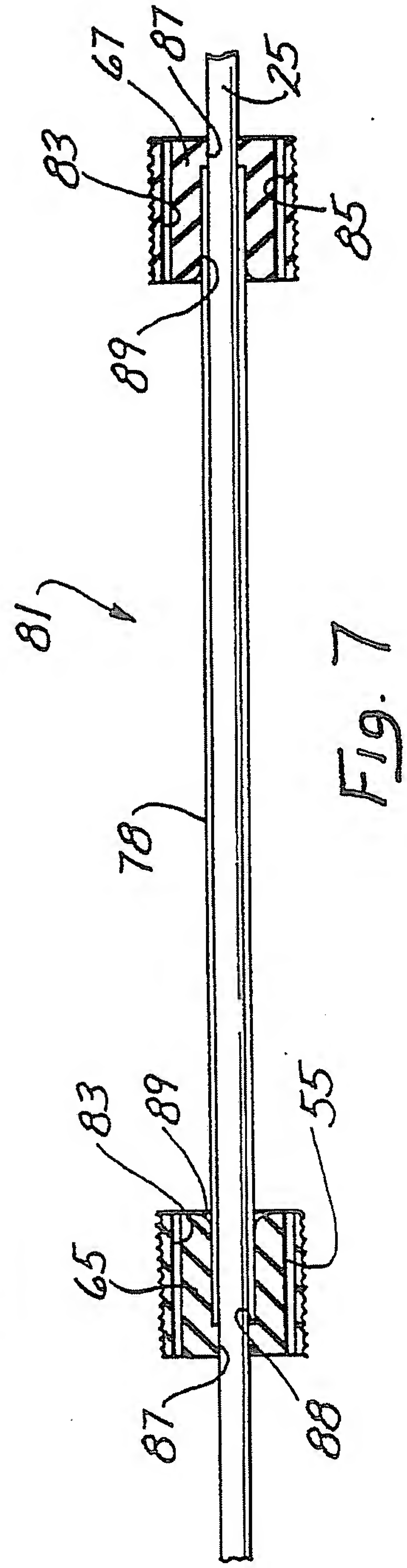
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Fig. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US93/04511

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :A61M 37/00; A61B 1/06
US CL :604/95; 128/4
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 604/95; 128/4,6, 657

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US, A, 4,934,340 (Ebling et al) 19 June 1990, see entire document.	1, 2, 4-9, 17-23
X	US, A, 3,610,231 (Takahashi et al) 05 October 1971, see entire document.	1-9, 17-23
A	US, A, 5,041,108 (Fox et al) 20 August 1991, see entire document.	
A	US, A, 4,753,223 (Bremer) 28 June 1988, see entire document.	
A	US, A, 4,737,142 (Heckele) 12 April 1988, see entire document.	

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be part of particular relevance
- "E" earlier document published on or after the international filing date
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- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 August 1993	20 SEP 93

Name and mailing address of the ISA/US	Authorized officer
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